Soybean Crop Rotation for Manitoba Farmers

Year 2 Annual Report

The objectives of this research project are to:
1. Identify the best crops to plant before soybeans in Manitoba.
2. Evaluate the agronomic consequences of planting soybeans in two consecutive years in Manitoba.
3. Quantify the nitrogen contribution of soybeans to a subsequent crop in Manitoba.
4. Investigate a potential cause of preceding crop effect on soybean yield; the effect of preceding crop on arbuscular mycorrhizal fungi colonization and nitrogen fixation of soybeans.

Project activities and research progress 2013-2014

Experiment 1: Identifying the best crops to plant before soybeans in Manitoba

This experiment studies the effect of different crop sequences on soybean yield. The sites selected for this experiment were the Ian N. Morrison Research Farm in Carman, Manitoba; Richardson International’s Kelburn Farm in St. Adolphe, Manitoba; and the Canada Manitoba Crop Diversification Centre in Portage, Manitoba. In the first year of the study, rotational crops of canola, wheat, corn, and soybean were grown. In the second year of the study a test crop of soybean was grown on the stubble of the preceding rotational crops. This sequence experiment was conducted at two locations (Carman, Kelburn) in 2012-2013 and at three locations (Carman, Kelburn, Portage) in 2013-2014. Measurements taken during the second year of the soybean test crop included seedling plant stands, phonological development, plant heights and harvest plant stands. Yield samples were collected when the soybeans were harvested in October.

The 2013 growing season was favorable with low disease and insect pressure at both sites. Soybean yield was excellent at Carman but poorer at Kelburn (Figure 1) mainly due to herbivory from rabbits and deer. The following year, electric fences were used to protect the experiments. Planting in 2014 was delayed due to the late and cool spring but seeding was completed by early June. The growing season was relatively good and disease and insect pressures were again low. There was a frost on September 11, 2014 at the Carman site which caused some frost damage to the upper canopy of the soybean test crop but likely had limited impact on soybean yield. Soybean yields in 2014 were highest at Carman and lowest at Portage (Table 1).

Significant crop sequence treatment effects in the soybean test crop were observed in three of the five site years of the experiment. Crop sequence did not have a significant impact on soybean yield at Kelburn in 2013 or at Carman in 2014. Wheat-Soybean and Corn-Soybean crop sequences were good rotational choices in all site years.

One objective of this project was to evaluate potential consequences of growing soybeans in consecutive years. Surprisingly, the soybean-soybean treatment was both the highest (Carman 2013) and lowest (Kelburn 2014) yielding treatment depending on site and year. The high yield for the soybean-soybean treatment in Carman 2013 was partly due to the presence of volunteer soybeans and we are still deciding how to account for these volunteers in the data analysis. A second
hypothesis that we wanted to test in this study was if growing canola before soybeans would reduce yields. This was due to the fact that soybean, wheat, and corn are all crops that will form mutualistic relationships with mycorrhizal fungi, while canola does not. Although the Canola-Soybean treatment was never the highest yielding treatment, it was the lowest yielding in only one of five site years (Portage 2014).

All field work has been completed for this experiment. Data analysis is underway for the 2014 and the final analysis of the combined 2013 and 2014 results. Due to the interactions between treatments at different locations and years, we will also be looking into the soil, weather, and plant data collected that could explain why some of the treatments behaved differently among the site years.

![Figure 1: Soybean test crop yields for Experiment 1 Crop Sequence Study in 2013. Letters indicate significant differences at the P=0.05 level.](image1)

![Table 1: Soybean test crop yields for Experiment 1 Crop Sequence Study in 2014. Letters indicate significant differences at the P=0.05 level.](image2)

<table>
<thead>
<tr>
<th>Site</th>
<th>Soybean Yield in bu/ac by Preceding Crop</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Corn</td>
</tr>
<tr>
<td>Carman</td>
<td>43.8 (A)</td>
</tr>
<tr>
<td>Kelburn</td>
<td>44.5 (A)</td>
</tr>
<tr>
<td>Portage</td>
<td>35.9 (AB)</td>
</tr>
</tbody>
</table>

Experiment 2: Interactions between mycorrhizal colonization and nitrogen fixation in soybean

Using samples collected from Experiment 1, this study focused on the relationship between crop sequence and biological nitrogen fixation by *Bradyrhizobium* bacteria as well as interactions with mycorrhizal fungi colonization of soybean roots. Arbuscular mycorrhizal fungi infect soybean roots and provide the plant with nutrients, such as phosphorus, in exchange for carbon based energy produced by the plant through photosynthesis. This symbiotic relationship can increase plant
growth and yield through the increased ability of the plant to take up nutrients. Our objective was to determine if different crop sequences had an impact on the degree of colonization by mycorrhizae.

Soybeans form a symbiotic relationship with *Bradyrhizobium* bacteria. The plant provides the bacteria with nutrients and the bacteria fixes nitrogen from the atmosphere, which is made available to the plant. Soybeans derive a significant portion of their nitrogen from this biological fixation. Our objective was to determine if different crop sequences had an impact on the ability of *Bradyrhizobium* to fix nitrogen. To do this we used the natural abundance method and harvested soybean plant at both the V3 and R5 stages. Canola was used as a reference crop. The plant biomass samples were ground and analyzed for the isotope $^{15}$N using a mass spectrometer. The spectrometer can determine the percentage of different nitrogen isotopes in the sample and that can be used to determine how much of the nitrogen in the sample was fixed biologically. Results from the 2013 soybean crop indicate that crop rotation did have a significant effect on biological nitrogen fixation (Figure 2.) As expected, the canola-soybean rotation always had significantly lower nitrogen fixation. Interestingly, the soybean-soybean crop sequence always had significantly higher amounts of nitrogen derived from biological nitrogen fixation. This may have been due to increased populations of *bradyrhizobium* when growing the two soybean crops in a row.

Soybeans also form a mutualistic relationship with arbuscular mycorrhizal fungi. To quantify the association between the soybean plants and the mycorrhizal fungi we sampled roots from Experiment 1 at the V3 stage and then applied a staining solution to the roots. The staining solution is strongly absorbed by mycorrhizal fungi, which can then be seen under a microscope. We counted the percentage of roots that were infected to determine the degree of mycorrhizal activity. Results from the 2013 soybean test crop indicate that crop rotation did have a significant effect on mycorrhizal colonization (Figure 3). Soybean plants that had been grown on soybean or corn stubble had significantly higher mycorrhizal colonization than plants growing on wheat or canola stubble. This confirms our hypothesis that crop sequences that include mycorrhizal plants will result in higher mycorrhizal populations and colonization of subsequent soybean crops.

Samples were collected during the 2014 growing season from Experiment 1 at all three locations to continue with the nitrogen fixation and mycorrhizal fungi analysis. Currently root samples are being stained and prepared for analysis under the microscope. Biomass samples have been ground for biological nitrogen fixation analysis. They are currently being packaged into capsules and will be sent for analysis at the University of Saskatchewan. We expect data collection for this experiment to be completed in February.
Figure 2: Percent of nitrogen in soybean biomass derived from biological nitrogen fixation in Experiment 2 Interactions between mycorrhizal colonization and nitrogen fixation in soybean at Carman and Kelburn in 2013. Letters indicate significant differences at the P=0.05 level.

Figure 3: Percent of soybean test crop roots colonized by mycorrhizal fungi in Experiment 2 Experiment 2 Interactions between mycorrhizal colonization and nitrogen fixation in soybean at Carman and Kelburn in 2013. Letters indicate significant differences at the P=0.05 level.

**Experiment 3: Rotational nitrogen benefit of soybeans**

The purpose of this experiment is to quantify the nitrogen contribution of soybeans to a subsequent wheat crop. Canola was used as a reference rotational crop in the experiment. The sites selected for this experiment were the Ian N. Morrison Research Farm in Carman, Manitoba and Richardson International’s Kelburn Farm in St. Adolphe. In the first year of the study rotational crops of soybean and canola were grown. In the second year of the study a test crop of wheat was grown on the stubble of the preceding crops and the plots were subdivided to incorporate a range of nitrogen fertilizer treatments to produce a nitrogen response curve. This sequence experiment was conducted in 2012-2013 and in 2013-2014. Measurements taken during the year of the wheat test crop included seedling plant stands, phonological development, total above ground biomass, wheat grain yield, as well as spring and fall residual soil nitrogen.
The experiments at both locations in 2013 produced excellent nitrogen response curves for the wheat test crops that followed soybean. The response curves for the wheat test crops that followed canola were not as expected. There was no yield response to nitrogen for the wheat test crop following canola at Kelburn in 2013. At Carman the yield of wheat following canola was greater than when following soybean across all nitrogen fertilizer rates. This suggests that there was no nitrogen credit from the soybean crop or residual fertilizer left over after the canola rotational crop. However, statistically analysis has not yet been performed and these differences will also be better understood after comparing the soil test data collected to quantify residual nitrogen in the soil following the canola treatment crop and the wheat test crop.

The 2014 wheat test crops were successfully harvested this fall. All field work has been completed for this experiment. Biomass samples have been ground and will be sent for nitrogen analysis soon. Data analysis is needed for both 2013 and 2014 as well as the final analysis of the combined 2013 and 2014 results. The plan to complete this analysis is discussed below.

![Figure 4: Wheat test crop yield response to nitrogen fertilizer rate when grown after canola and soybean crops in Experiment 3 Rotational nitrogen benefit of soybeans at Carman and Kelburn in 2013.](image)

**Extension activities:**

Extension activities in 2014 were limited compared to 2013 due to Dr. Lawley’s maternity leave. Don Sanders gave a field tour of Experiment 1 to board members of the Manitoba Pulse Growers Association in July 2014. Don presented a poster of the results from Experiment 1 and 2 at the Manitoba Agronomists Conference in December 2014. He will also plan to present the results of this research at the Canadian Society of Agronomy annual meeting in July 2015.